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IDEO-MOTOR ACTION[1]

THE problem of ideo-motor action has again been brought to the foreground by Professor Thorndike, who has called in question the orthodox view that an idea of a movement, in and of itself, has power to produce that movement. Pedagogical methods resulting from this doctrine, such as imitation, teaching children how to do given acts by acting the part before them, and reading tales of the noble and heroic as a means of developing character, are dismissed as factors in education. The reasons for this conclusion, I believe to be well grounded and to require no review. But they raise the questions: Are we, then, to conclude that ideas are of no use at all in conduct? If ideas of *movements* do not produce action, what sort of ideas *do* lead to action and *are* of value in education and pedagogy? It can not be denied that all our teaching, preaching, writing, and legislation are based upon faith in the motive power of ideas, and it is of primary importance to know what sort of ideas will lead to the results desired by these activities. The most positive statement upon the latter question that I find in the recent "Educational Psychology" is the following: "If the doctrine of this book is true, suggestion will succeed in so far as it is a process of manipulating a person's ideas and attitudes so as to get him into a situation to which the desired response rather than another is connected by the laws of instinct, exercise, and effect."[2] From this and other passages I infer that ideas have some efficacy in getting a person into the right situation, and function in that situation through some stimulus-response connection. At any rate I shall take this suggestion as the text of my paper and, upon this basis, attempt to show in some detail the value, functioning, and working of ideas.

The question of the value of an idea is as old as philosophy, but, strange to say, twenty-seven hundred years of speculation have failed to bring any agreement upon the solution. Whether this is a refutation of the speculative method or a proof of the insolubility of the problem I shall not try to decide. But it appears that an ancient statesman and a modern philosopher do agree upon the function of thought, and both upon empirical grounds. These are Pericles and Dewey. The former attributed the power of Athens to the power of thought. He said: "The great impediment to action is, in our opinion, not discussion, but want of that knowledge which is gained by discussion preparatory to action. For we have a peculiar power of thinking before we act, and of acting, too; whereas other men are courageous from ignorance, but hesitate upon reflection." The latter, viewing thought from a biological standpoint, came to the conclusion that its business is not to transcend nature or to create in idea a mystical and beautiful object of contemplation in the form of an eternal and absolute world, but to direct conduct and solve its problems. Such an agreement between a practical man and a philosopher is as worthy of attention as it is rare. When a philosopher, after reflection upon the power of thought, decides not to set it up as a divinity in some far away world of magic and wonder, but says that the place of its birth is not too humble for its functioning, it is but a step to the suggestion that thought, like other natural functions, is subject to experimental treatment, and that possibly this method as the opposite of the speculative will tell us more exactly how thought controls and directs conduct.

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[1] Read before the Psychological Club, Columbia University, March 12, 1914.

[2] Thorndike's "Educational Psychology," Vol. 1, page 293.

In agreement with this suggestion we shall view ideas or thought as a form of conduct and subject to the principles controlling conduct in general. To discover, then, the action of thought we shall find it helpful to consider genetically the conditions under which conduct occurs or responds.

Beginning with the behavior of the lowest animals, we notice that conduct is always in response to some stimulus coming from the environment, and further that the character of the stimulus determines the character of the response. For example, if an amœba is given a strong mechanical stimulus, it moves away; if it is given a weak mechanical stimulus, it moves toward the stimulus; and if a small particle of food is placed at its side, it envelops it.[3] If the anterior end of an earth-worm is touched, it creeps backward; if the side is touched, it turns away; if the posterior end is touched, it creeps forward;[4] and if it is thrown on its back, it twists around upon its ventral side.[5] The "flexion," "scratching," and "clasping" reflexes in a frog are other examples.

If we pass to higher forms, the stimulus-response principle holds throughout; but a great variety of objects may act as a stimulus setting off an equally great number of responses. The connection between particular response and particular stimulus is, however, definite and is determined by the character of the situation on the one hand and the physiological condition on the other. For example, the perception of a wire loop, a button, a string, a thumb latch, a door, etc., by a hungry dog or cat placed inside a box having food on the outside may set off the necessary movements for getting out and securing the food. If a hungry South American cebus monkey[6] is placed in a cage and an experimenter with some food is on the outside, the monkey can learn to reach for food when the experimenter picks it up with his left hand, or shows it a white, diamond-shaped card-board, or a single brown card, or a card with a black ring on it; or if he picks up food with his left hand from a pile directly in front of the bar, or picks it up from a small brown pasteboard box. The monkey learns not to reach for food or change his reaction from the ordinary when the experimenter picks up food with his right hand, or shows it a black, diamond-shaped card-board, or a white and gold card, or a card with two black concentric rings on it, or takes food from a dish a short distance in front of the cage, or when he swings his left forearm diagonally around from his right side, or picks up food from a white crock, or a small saucer. The monkey was taught these various discriminations by being rewarded with food when he made the reaction desired by the experimenter, and not rewarded when its reactions were otherwise.[7]

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[3] Jennings, "Behavior of Lower Organisms."

[4] Jennings, *J. of Ex. Zool.*, Vol. 3, page 435.

[5] Pearl, *Quar. J. Micro. Sci.*, Vol. 46, page 509.

If rewarded with food after a successful trial, a trained hungry rat will run a complicated maze without error as soon as it is placed inside it. If placed before a box containing food and banked with sawdust, or if the door is pasted shut with strips of paper, the perception of the sawdust or the strips of paper will, after a learning period, lead to the proper reactions for getting to the food.[8] Raccoons can learn to climb upon a box to be fed when a high note is sounded or when a large card is shown, and to stay down when a low note is sounded or when a small card is shown.[9] Further examples need not be cited to show that animal learning is dependent upon the perception of particular stimuli under particular conditions and situations.

We shall now pass to human learning. Here experimentation shows no exception to the stimulus-response principle. Apparently there are no reactions, however refined, which do not take their origin from a sensory cue of some kind. Just as there is no spontaneous generation of fermentation or life so there appears to be no spon-

[6] Thorndike, *Psych. Rev. Mon. Sup.*, Vol. 2, No. 4.

[7] Thorndike, *Psych. Rev. Mon. Sup.*, Vol. 3, No. 5.

[8] Small, *Am. J. of Psych.*, Vol. 12, page 206.

[9] Cole, *J. of Comp. Neur. and Psych.*, Vol. 17, page 211.

taneous behavior of the nervous system involving only the so-called motor paths. On the contrary, control of voluntary movement depends upon perception of the adequate stimulus. One of the first experiments relating to this point was made by Bowditch and Southard, who tried to touch a given point first by fixating it with the eyes, then closing the eyes and touching the same point by relying upon the muscular sense. They found that the movements were more accurate when accompanied by vision.[10] Bair trained fourteen subjects to move their ears with the *retranens aurem* muscle, usually an entirely unused muscle. He found that they succeeded after they had isolated and could attend to the particular sensation resulting from the movement of this muscle.[11] Professor Woodworth made an experiment in which he aimed to move his big toe while keeping the others quiet, and found that he succeeded after he could once exclusively attend to the sensation resulting from its movement.[12] He concludes that the sensation of movement is necessary in the acquisition of voluntary control; that a reproduced image of the sensations is valuable in reporting whether the result has been attained; but that the power to recall an image at will is not equivalent to acquiring voluntary control; and that the latter does not depend on kinesthetic images. He later made a more extended study of the same problem, in which he discovered that images are unimportant for the control of simple automatic acts like opening the eyes or wagging the jaw. Such acts can be performed immediately upon the reception of the external stimulus without the intervention of imagery. The fact that images are unimportant in such cases does, however, not prove that they are equally so in the learning of complex voluntary acts like typewriting or telegraphy. Another important contribution in this study is a pointing out of the value of "set" in voluntary control. Upon this Professor Woodworth says: "When a man confronted by a novel situation observes this and that feature of it in turn, each new perception leaves behind in the nervous system a temporary adjustment to the feature observed, until the whole situation becomes, not clearly mirrored in any one moment of his consciousness, but dynamically represented by the sum or resultant of these partial adjustments. If he then thinks of some change that he can make in the situation and decides to make it, the definiteness of his intention is not contained wholly in the field of attention at that moment, but depends upon the total neural set, and so on the total situation."[13] Later investigators, as we shall see, have confirmed this conception, but have found that a long practise series is required to make the organization of ''set'' definite and effective.

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[10] *J. of Physiology*, 1881, pages 3, 232 ff.

[11] *Psych. Rev.*, Vol. 8, 1901, pages 474–510.

[12] "Le Mouvement," pages 330 ff.

[13] "Garman Memorial Volume," page 391.

A very important study on voluntary control has been made by Miss Downey,[14] who experimented with handwriting for the purpose of determining the importance of imagery. She found that while her subjects were dependent on sensory cues of some kind for the control of the writing process, no two used the same imagery throughout. Three of her subjects depended primarily upon automatic or muscular control; and four, on conscious control. But all depended on visual cues to some extent, it being most prominent in those using conscious control. Auditory imagery was prominent in three, and conscious grapho-motor in two. These results may be illustrated by referring to some of her tests. When her subjects wrote blindfolded, all showed mistakes in spacing, alignment, and in beginning the lines at the margin. Blindfolded writing with the left hand showed further deterioration in these respects. In inverted writing one succeeded by vocalizing the words and starting with a definite intention to invert. Two started with visual cues, but afterwards depended on muscular control. One visualized the letters upright and then inverted them mentally and wrote. One visualized the letters upright, inverted them, reversed, projected the image on the paper, and then wrote. Two subjects failed in this process because of inadequate sensory cues. For example, D., who was dependent on visual imagery, could not adequately visualize the letters upside down. These individual differences are further illustrated in the tests in which the subjects were required to write with a tablet placed on the forehead, or on the top of the head, or parallel to and at right angles with the back, or over either right or left shoulder. Three succeeded in these various forms by imagining the results as in normal writing such as looking down on the writing from above and at the left. Three others had no visual imagery, but depended upon kinesthetic reports and anticipatory motor cues. The peculiar dependence of the result upon the character of the imagery is illustrated in the case of S., who, in writing from left to right on top of the head, saw the letters as from below, with the result that the writing was reversed. But when he saw them as from above the writing became normal. There was a similar result in the case of H., who wrote mirror fashion upon the forehead, but at times reproduced normally when she imagined herself seeing the letters from the front. The best tests, however, which Miss Downey made to bring out the importance of imagery were such as writing with eyes open while counting aloud, reading aloud, counting mentally the number of times a particular word occurred in a rhyming list read aloud by the experimenter, or writing blindfolded and counting aloud. From these tests we may expect that if a writer depends on a given sensory cue, a distraction affecting that cue will raise his writing time more than any other distraction. For example, if a writer depends upon articulatory or vocal motor control, reading aloud will raise his writing time more than writing blindfolded. The results were in agreement with these expectations. If a writer's usual sensory cue was interfered with, his writing time was raised much above the normal, but this was not the case when the distraction affected an unusual cue. When those who depended on voluntarily produced imagery had their attention completely distracted, they found it impossible to write. Another interesting result was that when a used cue was distracted, the writer could shift to another, *e. g.*, change from visual control to articulatory or auditory. But the principal result of the experiment is that the control of every voluntary act depended upon some sensory cue. If this cue could not be secured in perception, it was supplied by imagery.

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[14] *Psych. Rev. Mon. Suppl.*, Vol. 9, 1908, pages 1–148.

Judd[15] assisted by McAllister, Steele, Cameron, and Courten made a series of experiments that have a bearing upon our problem. These included three experiments upon illusions, one upon reaction time, and one upon practise without knowledge of results. In the experiments upon illusions the eye movements were photographed both at the beginning of a practise series, when the illusion appeared, and at the end, when the illusion disappeared. In the Müller-Lyer illusion it was found that before practise the eyes made many more pauses in the underestimated area than in the overestimated area; but after the practise series, the eyes moved with equal facility along the entire line and made an equal number of pauses in each field. In the Poggendorf illusion it was found that before practise the eyes moved along the oblique irregularly, making frequent and long pauses at the points of intersection with the verticals. After practise the eyes moved along the oblique line with almost no deflection, with fewer and more equally distributed pauses, and with shorter and more rapid motion. In the Zöllner illusion it was found that before practise the eyes moved along the long parallels very irregularly, making many pauses at points of intersection, many deflections, and many twists. After practise there was a close adherence to an undeflected and regular movement along the long lines with pauses at regular intervals. In the reaction experiment the movements of the reacting hand both before and after the reception of the get-ready stimulus were recorded on waxed paper. The record showed a marked unsteadiness of the hand after this signal, indicating an increasing tendency to react. In the practise experiment without knowledge of results the subject was required to indicate the projection of a series of oblique lines both above and below a given horizontal. Two hundred trials upon each line distributed over a period of ten days showed no improvement. A series of tests with knowledge of results was then made upon two obliques, one forming an angle of 60 degrees above the horizontal, the other an angle of 45 degrees below the horizontal. A practise series distributed over ten days corrected the error with the first line, but increased it with the second. The correction of the first line was effected by placing the projection at a point higher than the first point indicated. The same habit was transferred to the second line with adverse results. What is significant in the illusion experiments for our purposes is that when the perception of the illusion disappeared the sensory stimulus was different from what it was in the illusion. The reaction experiment indicated that the reception of a sensory stimulus tends to be followed by a motor response even when it should be inhibited, and the reaction experiment indicated that perception of one's results of reactions to be perfected changes the character of those reactions. In each case control of the reaction depended upon getting the right sensory cue.

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[15] *Psych. Rev. Mon. Suppl.*, Vol. VII., 1905, pages 1 ff.

Another series of experiments bearing directly upon our problem are the so-called practise experiments. Hitherto attention has been directed principally to the amount of improvement of a given function, its persistence, and the form of the practise curve. A careful review of the literature, however, points to the conclusion that improvement in a given function depends in a great measure upon the forms of perception to which the desired movements are made. Leuba and Hyde,[16] who had students practise writing English prose in German script by the aid of a copy of the German script alphabet, found three stages of progress. In the first stage the student pronounced in inner speech the English letters separately, then associated them with the perception of the German letters which were pronounced in inner speech and then written. In the second stage, the inner speech process dropped out and the writing of the German letters followed immediately upon the perception of the English letters. In the third stage the English letters were no more perceived separately, but in word and phrase groups and written in the same units. It is interesting to note that in each stage the units of reaction correspond with the units of perception.

Rowe[17] in an experiment designed to analyze the sensory processes in voluntary control had four subjects practise, until the reactions became automatic, writing ten standard words by pressing small rubber bulbs arranged so as to correspond in number and letter order to the lower row of keys in a Blickensderfer typewriter. The letters were indicated by means of a cardboard placed in front of the bulbs. In general, during the first stage of development, the subjects had to look at the stimulus words, pronounce them in inner speech, pronounce each of the letters in inner speech, and find them on the cardboard, and then look at each letter carefully while pressing the proper bulb, often dividing the attention between the cardboard letter and the pressing movement. In a second stage, the perception of the cardboard and the keyboard were eliminated and the reactions followed upon the memory image of the copy. In the third stage, after the ten words could be written in one series of coordinated finger movements, perception of details was eliminated and there remained only a general "set" characterized by attention to the situation as a whole in which were present general bodily, tactual-kinesthetic, and visual sensations. Inner speech still occurred in some cases, but was unimportant, for many of the reactions preceded the inner speech. His conclusion from his observations is that without sense-processes relevant to the situation purely ideational processes are incompetent to initiate movements. Sensations are the *sine qua non* of consciously controlled acts. In the development of voluntary control the correct movement is first made reflexly, certain sense elements connected with it are then caught by the attention and are made functional through its effect. In the highest volitional processes both clear perception and clear imagery are necessary, but attention may leave the process through the substitution of the general symbol for the details of the original.

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[16] *Psych. Rev.*, Vol. 12, 1905, page 357.

[17] *Am. J. of Psych.*, Vol. 21, 1910, pages 513 ff.

Another experiment which shows the close dependence of voluntary control upon the form of perception is Book's study of skill in typewriting.[18] In this connection the short-circuiting in the perceptual processes in the development of speed is interesting. This may be illustrated with reference to those using the touch method. The subjects committed the keyboard to memory, after which it was screened and the process of writing begun. The subjects first got the copy; second, pronounced the letter; third, located it mentally on the keyboard, for example, from a visual image of its correct position; fourth, got the finger on the proper key by first locating its row and then counting and feeling the individual keys until the proper one was found; fifth, pronounced the letters again and made the correct movement. It is little wonder that during the early stages the letter to be written was sometimes forgotten during this complicated process. Improvement was made by a gradual fusion of these steps. The initial spelling fused into the sight of the letter so that the remaining processes followed successfully upon sight of the letter. The mental locating of the keys and the complicated finger movements made to find the right key fused into a motor-touch image so that as soon as the letter was seen it could be correctly located by getting a "feel" of the movement necessary to hit the desired key. Later the motor part of the image dropped out and the correctness of the movement was recognized by touch alone. Finally the inner spelling also dropped out so that the sight of the copy led directly to the proper reaction. The inner spelling, however, reappeared whenever difficult words were met.

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[18] "Psychology of Skill," 1908.

In a second stage the learner reads and writes in syllable and word units. One subject describes this process as follows: "An easy word is taken in as a whole; a few short easy ones are taken in as a connected series. A long and difficult word may be broken up into groups of easy familiar combinations, or in case of extreme difficulty, it may be incipiently spelled letter by letter, and by attending to each individual movement. This way of spelling words or taking in familiar parts of them, and the manner of the movements seem to run closely parallel all the time. I take a thing in on the keyboard just as I take it in in the copy—by letter, by combinations of letters, by words or groups of short easy words."[19] The same subject is again quoted as follows: "A word simply means a group of movements which I tend to as a whole. I seem to get beforehand a sort of "feel" of the whole group which is run through with that sort of conception and direction of attention."[20] In learning to make group movements inner spelling was at first necessary to give the right sequence, but when the groups became familiar it faded away.

In the expert stage, phrases, clauses, and sentences became the unit of attention. Movements were no longer attended to in word groups, but attention was directed toward getting through with the sentence as a whole and with performing the movements in the right succession. The eyes were kept continuously on the copy a number of words ahead of the hand. The pronouncing of the words served to start and control the series of movements.

Such in outline is the order of development in learning to typewrite by the touch method. The genesis in the sight method is not characteristically different in principle. It will be found that the genesis is of the same character as other investigators have found, beginning with sharp attention and perception of every detail and ending with attention and perception directed to the process as a whole. It may be asked why this cumbersome process must be gone through in the learning of skill and why we can not begin writing in sentence units at once instead of worrying with the drudgery of letters. One reason may be the physical resistance of the muscular tissue to a sudden adaptation to such complicated movements. But I doubt whether this is the chief difficulty, because the muscles of the young are extremely flexible. I venture to suggest that the difficulty lies rather in the nervous system, in its inability largely to get adequate sensory stimuli. A sentence can not be written upon the perception of a single letter. This requires a perception of the sentence as a whole and a feeling of the entire series of movements as a whole. In other words, the unit of reaction must correspond to the unit of perception. The converse of this proposition may be equally true. It is altogether likely that the limit of the unit of perception is determined by the limit of the reaction. But this does not gainsay the contention that voluntary control depends upon perception.

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[19] *Idem,* page 38.

[20] *Idem,* page 39.

If it is true that voluntary control depends upon the perception of the adequate stimulus, then we should expect a loss of this function to follow upon an elimination of the sensory cue. There is some physiological, pathological, and clinical evidence in favor of this view, but not as much as we could wish for. Bernard[21] made an experiment in which he produced total anesthesia of a frog's hind feet by cutting the sensory spinal roots innervating those parts. The result was a failure in the coordination of the feet. Mott and Sherrington made a similar experiment on a monkey by cutting on one side of the cord the dorsal roots of the nerves supplying the arm and the leg. The authors conclude that volition in these members was absolutely abolished by this operation.[22] Sherrington, reporting on a second experiment upon this problem, concludes that destruction of sensitivity in particular regions causes objectively observable disturbances of movement. "The effects of the anesthesia upon the musculature of the part are three—(1) paralysis, (2) ataxia, (3) atonia."[23] Munk in repeating the experiment of Mott and Sherrington concluded that voluntary control does not depend upon the muscular sense alone, but may be recovered by practise through other senses like vision. Flourens noticed that cutting the semicircular canals in pigeons caused confused and disordered movements.[24] Ewald, repeating the experiments, found that extirpating a canal on one side caused a twisting of the head, an unequal extension of the feet, and an inclination of the body toward the injured side.[25]

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[21] "Leçons sur la Physiologie du System Nerveux," Paris, 1858, pages 1, 251.

[22] *Proc. Roy. Soc.*, Vol. 57, pages 481 ff.

[23] *Ibid.*, Vol. 61.

[24] "Researches Experimentales sur les Proprietes et les Functions du System Nerveux," 2d ed., 1842, pages 452 ff.

[25] "Physiologische Untersuchungen über das Endorgan des Nervus Octavus," 1892.

There was a loss of normal balancing movements on that side. Turning to some pathological and clinical evidence, Gley and Marillier[26] report a case of a patient deprived of all sensibility in the upper half of his body. When blindfolded the patient's arms could be moved in any direction by the experimenter without his being able to describe their position, he could not discriminate between a weight of 250 grams and one of 1,850 grams, nor tell the difference between hard wood and soft rubber, nor make movements upon command. Bleuler[27] describes a case of total anesthesia on the right side, in which the patient could not move his right arm except when he saw it. A. Pick[28] reports a case of complete loss of deep and superficial sensibility on the right side. The patient could open and close her right hand when she fixated upon it, but not when the hand was outside the center of vision. Berkeley[29] reports a case in which there was total loss of thermic, pain, olfactory, gustatory, equilibrium, pressure, and weight sensations, an almost total loss of vision, a partial loss of muscular sense, and a progressive dulling of hearing. The patient, who had not lost sanity, could not move the indicator in a dynamometer upon command, although she made every effort to do so. She could not help herself in any way.

Hoppe[30] describes a case in which the muscular sense and the sense of the position of the limb were almost absent. The right arm seemed completely paralyzed and the patient could not move it upon command. But she learned to do so by watching the doctor's hand move and then repeating the movements.

These cases point to a close dependence of voluntary control upon some kind of sensation and that, in case of need, there is possibility of transferring control from one sense to another. Such shiftings are similar to those reported by Miss Downey.

What we have gained from this review of experimental evidence on the sensation-movement relationship is: (1) that both human and animal behavior takes place in response to sensory stimuli; (2) that the character of the stimulus determines the character of the response; and (3) that control of the response depends upon control of the stimulus. Propositions (2) and (3) are still open to further experimentation. But the findings of Bryan and Harter, Book, Leuba, and Rowe upon the specific correspondence between perception units and reaction units, and Judd's discovery of the disappearance of illusions after the sensory stimulus was under control, leave little room for doubt. At least it is safe to accept them as favorable hypotheses. It will be observed that no fiats of will are reported, no so-called feelings of innervation, nor feelings of the muscles and joints in movement. These are superfluous intermediaries between the stimulus and the response. Control is obtained by attention to the stimuli and to the results of the movement. Perception of the results of one's movements is rather a stimulus for the following movement.

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[26] *Revue Philosophique,* 1887, XXIII., pages 441 ff.

[27] *Archiv für Psychiatrie und Nervenkrankheiten,* 1893, Vol. 25.

[28] *Zeit. für Psy. und Phys. der Sinnes.,* Vol. 4, page 175.

[29] *Brain,* Vol. 23, page 14.

[30] *J. of Mental and Nervous Diseases,* Vol. 32, page 145.

If the above conclusions are accepted we have not far to go to find the function of ideas. It will be recalled that Bair's subjects could move their ears after they could attend to the sensation resulting from their movement, and Professor Woodworth could move his great toe after he could attend to the sensation produced by its movement. In trying Bair's experiment upon my left ear, I discovered that after the ear once got into motion the new position of the muscles produced a new sensation. It was not a sensation of the muscle in motion, but a sensation of the muscle after this motion was completed. Attending to this sensation independently gave me control over the desired movement. This and the other experiment reported suggests that the function of ideas or cognition is to analyze the sensory stimuli to which conduct responds. These stimuli may then be caught by the attention and responded to voluntarily. A change in conduct is then effected through attention to a different stimulus. Why I respond to one stimulus rather than to another is due to a complication of factors such as those of instinct, habit, desire, and satisfaction, but in particular, to the interest of the present moment. For example, just now I am interested in writing this paper. I attend only to those things which have a relevancy to my problem. I see hundreds of books before me, but I open and read only a few of them. If I should read a classical periodical which I now see it would pain me as a waste of time. That is, I am adjusted to respond only to matters concerning the ideo-motor problem, and have developed a temporary set to that effect. I developed this set in response to a problem which was again brought vividly to my attention by reading Thorndike's "Psychology" because of a general interest in the science. I might continue giving account for my interest in psychology, and so on indefinitely; but the point I wish to make clear is that "set" is a temporary response of the nervous system as a whole to a present situation and is in turn determined by my past conduct. It is therefore due in part to present stimuli, but probably more to responses to stimuli in the past.

Reverting to the problem of the function of ideas, I wish to describe more in detail the process of analysis. For example, when a boy goes through the Columbia library and begins turning off the lights, the sensation produced is a stimulus to get out and to go home for rest. Going out of the building, down wooden steps, and out at a narrow wooden gate is a stimulus to turn north. Coming to a show window in which are displayed wines and candies is a stimulus to turn west. Going up a hill and seeing iron posts on each side of stone steps is a stimulus to turn in. Before I had analyzed the characteristic stimuli at each turning point, I could not find my way without error. I turned west at the wrong block or in at the wrong door. I then set to work and made a comparison of the marks at each corner where I should turn and picked out certain easily distinguishable marks which were peculiar to each and which I could take as a never failing stimulus to turn in a certain way. After I had done this I could find my way home without apparently seeing anything. This analysis and fixation of the proper stimuli is accomplished through my ideas and power of cognition.

In the most highly technical scientific process the function of ideas is nothing different. Experimentation is simply an accurate means of finding and analyzing the proper stimuli for the formation of judgment and conduct. For example, before the time of Galileo, the Aristotelians said that bodies fall in proportion to their weight, that each body seeks its natural place, and that the natural place of a stone was on the earth and of a feather in the air, etc. These are accurate descriptions of our sense-perceptions in daily life. Galileo noticed from general observation that the velocity of a falling body was constantly on the increase and conceived the hypothesis that the velocity is proportional to the distance descended through. Finding, as he thought, a logical contradiction in this theory, he made another according to which velocity is proportional to the time of descent. Finding no contradiction in this view, he proceeded experimentally to verify it, by rolling balls down an inclined plane and measuring the times of descent. The time was measured by means of a water clock consisting of a wide vessel with an orifice at the bottom which was closed with the finger. As soon as the ball began to roll Galileo removed his finger and let the water run into a balance. When the ball reached its terminus, he closed the orifice. He found that while the times or units of water increased simply the distances increased quadradically—*i. e.*, that the distance varies directly as the square of the time of the descent.[31] What prevented Aristotle from reaching this conclusion was that he had no means of analyzing his gross perceptions. Galileo devised a means, in the inclined plane, water clock, and balls, which enabled him to make accurate perceptions and find the proper stimuli upon which to form a judgment. This way of devising an experimental method of analysis is the function of ideas.

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[31] Mach, "Science of Mechanics," page 130 ff.

In this connection I must also make a brief reference to the work of Pasteur[32] on fermentation. Before and during his day fermentation was believed to be due to spontaneous generation. Grape juice and milk soured very soon after extraction and apparently without the addition of new elements. The hypothesis of spontaneous generation was therefore an accurate description of the gross sense perception of the phenomena. Pasteur, however, submitted milk and other liquids to experimentation, using a more vigorous technique, and succeeded in showing that fermentation was due to foreign particles coming in contact with the liquid, particles in the surrounding air or in and around the containing vessels. His paper on lactic fermentation, which published this result, is a classic example of the power of an idea. A copy fell into the hands of a young surgeon of Scotland, Dr. Lister, who concluded from this paper that probably putrefaction in wounds was a form of fermentation caused by particles in the air and on the surgeon's hands and tools which came in contact with the wound. He therefore began operations in which the wounds and the surgeon's hands and tools were thoroughly cleansed by a solution of carbolic acid, and in two years discovered that out of forty patients upon whom amputations were made thirty-four recovered. The meaning of this may be gathered from the fact that during the same time in Paris where antiseptic surgery was not practised the mortality after amputation was 60 per cent., and during the siege of Paris almost every one operated on at the Grand Hotel, the temporary ambulance, died of purulent infection.

Another copy of this paper fell into the hands of one of Pasteur's countrymen, Davainne, who had observed small filiform bodies in the blood of animals that had died of anthrax,—a disease which annually killed 20,000,000 francs worth of domestic animals in France. Pasteur's paper suggested that probably the filiform bodies he had observed caused the disease in a manner similar to those causing fermentation. He verified his hypothesis by successfully inoculating healthy animals with the blood taken from the diseased animals. Koch, from Berlin, later took up the study and succeeded in isolating the particular germ causing the disease. Pasteur took up the study and by attenuating the virus containing the bacillus anthracis discovered a vaccine which rendered animals immune to the disease. This alone meant an annual saving of 20,000,000 francs to France, which gives a quantitative notion of the value of one of Pasteur's ideas.

We can not go into the study of Pasteur's work any farther.

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[32] Vallery-Radot, "Life of Pasteur," Mrs. Devonshire's transl.; Pasteur. "Studies on Fermentation," Faulkner and Robbs's transl.

It is sufficient to mention that some of the results which sprang from the new ideas contained in Pasteur's study of lactic fermentation are antiseptic surgery, the cure of anthrax, hydrophobia, diphtheria, and in general the processes involving antiseptics and serum-therapy. The value of this resists a quantitative estimate. I refer to this not as a matter of history, but to illustrate the value and working of ideas. Pasteur by means of an exact technique succeeded in analyzing and isolating the proper stimuli with reference to fermentation. He puts his findings into language, and publishes them. The paper crosses the sea and falls into the hands of a sagacious reader in a foreign land. The result is antiseptic surgery. This alone illustrates the process. The reasons that, before Pasteur, surgery, diphtheria, rabies, etc., were the plagues and decimators of humanity are that no one knew to what stimuli to react in these phenomena. It was left to the ideas and cognitive powers of Pasteur to devise an exact technique and analyze those stimuli, and after that analysis, control at once followed and the dreaded evils vanished. The work of Pasteur in itself proves that ideas produce productive action and results when they are of the right sort and point out the right sort of stimuli.

If this paper has accomplished its aim in showing that the work and function of ideas is to analyze stimuli to which conduct responds, we are in position to understand why an idea of a movement does not produce it; and why imitation, the teaching of animals and children how to do certain acts by acting the part before them, or by putting them through the desired acts, and the reading of tales of the noble and heroic are usually ineffective in getting the desired results. They fail to point out the proper stimuli to which the desired acts are a response. On the other hand, such methods, as well as preaching, lecturing, making laws, and writing books, do yield productive results when they succeed in pointing out the proper stimuli for the conduct desired. Such activities need, therefore, not be stopped for fear that ideas will produce no movements, but it is necessary that they be directed toward the adequate stimuli.

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VALUES AND EXPERIENCE[1]

IN a recent paper[2] I tried to indicate how scientific thinking is to be recognized as only the more reflective stage in man's vital enterprise of exploring and manipulating the rich world about him,

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[1] Read at the annual meeting of the American Philosophical Association, New Haven, December 29, 1913.

[2] *Philosophical Review*, Vol. XXII., pages 520–538.